MINISTRY OF WATER AND IRRIGATION

Water Resource Policy Support
Groundwater Management Component

GROUNDWATER ABSTRACTION METERING AND MONITORING, AMMAN-ZARQA BASIN

June, 2001

The Water Policy Support activity is supported by
the United States Agency for International Development (USAID) through a
contract with Associates in Rural Development, Inc. (ARD):
USAID/ARD Contract No. LAG-I-00-99-0001800, Delivery Order No. 800

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Executive Summary

A useful indicator for monitoring groundwater management is the annual rate of water abstraction as compared to aquifer recharge. This requires means for measuring or estimating the volume of groundwater abstracted with sufficient reliability and accuracy.

The Rapid Appraisal field survey results, reported in MWI/ARD January 2001,[1] indicate that of the 491 irrigation wells in the AZB, 94% have meters installed. The Water Authority of Jordan (WAJ) installed about 60% of these meters and farmers installed the rest. Only 61% of the meters were in working order. This resulted in gaps in the groundwater abstraction data.

The analysis of two alternative methods for estimation of irrigation water use abstraction, the first based on electricity consumption and the second uses remote sensing and crop water requirement, revealed that neither electrical consumption data nor remote sensing data should be used as replacements for metering in determining groundwater abstraction in the AZB, but they would be considered as supporting tools. The electrical energy consumption data can be used only to estimate groundwater abstraction as a spot check of individual well meter readings. Estimation of water abstraction by remote sensing data is still dependent upon theoretical crop water requirements and estimates of water use efficiency. However, remote sensing is a reliable method for monitoring changes in cropped area from period to period. Therefore, it is recommended as a support tool for monitoring the implementation of groundwater management options, especially the monitoring of cropped area and wells buyout.

This study concluded that the most accurate and reliable method of measuring groundwater abstraction is by water meters. A review of the irrigation well metering program and a practical plan and cost to improve the reliability and accuracy of the metering of irrigation water abstraction are presented in this report. The plan includes:

- Establishment of a meter repair and maintenance system
- Standardization of meters and meters installation
- Strengthening of metering operation
- Data reporting and management
- Water users education and awareness

The cost of the program is approximately estimated at around JD286,000; which includes costs related to the establishment of repair/maintenance crew, the replacement/rehabilitation of meters, and training of meter readers and repair/maintenance crew. The wells buy out option may make many meters available for use on other wells to standardize the meters. The purchase of replacement meters could be done through the use of the Groundwater Management Fund.

[1] MWI/ARD. January 2001. Study of Groundwater Use and Users in Northeastern Amman-Zarqa Basin Highlands.

Acknowledgements

This report was prepared by David Cone and Mohamed Chebaane. Special thanks to Kamel Radaideh, Bob Yoder, Lana Naber, and Ahmed Abu Hijleh for their valuable input.

The effort and contribution of MWI and WAJ Counterparts are acknowledged and highly appreciated: Edward Qunqar, Director of Water Resources Planning, Suzan Taha, Director of MIS, Eng. Mohammed Hunaty, WAJ, and Eng. Naser Nabulsi, WAJ.

1. Introduction

One of the two primary objectives of the Water Resource Policy Support (WRPS) activity is to design, institute and support a program for sustainable management of the upland aquifers in the upper Amman-Zarqa Basin (AZB). While recharge varies annually depending upon rainfall, studies have identified the long-term average recharge rate. A useful indicator for monitoring groundwater management is the annual rate of water abstraction as compared to aquifer recharge. This requires means for measuring or estimating the volume of groundwater abstracted with sufficient reliability and accuracy.

The most accurate and reliable method of measuring groundwater abstraction is by water meters installed on the discharge pipe of each well. The rapid appraisal (RA) field survey results, reported in MWI/ARD January 2001,[2] indicates that of the 491 irrigation wells in the AZB, 94% have meters installed. The Water Authority of Jordan (WAJ) installed about 60% of these meters and farmers installed the rest. This does not include the meters installed on domestic and industrial wells. While the majority of the wells have meters, only 61% of the meters were in working order (Table 1). Of the six wells inspected on 23 April 2001, only 1 meter was working and it was not working properly, however, during the time of the field survey three of these 6 meters were working. While an intensive irrigation well monitoring program is in place it appears that many of the meters are in need of repair in order to provide accurate readings. On the other hand, more than 90% of private industrial well meters, which are of the same brand as the irrigation well meters, are working. The reason is obvious, industrial well meters have priority at the WAJ repair shop because the significant charge (JD0.250/m3) paid by industrial well users.

This report reviews the irrigation well metering program and suggests ways to improve the reliability and accuracy of the metering data. It sets out a practical plan and cost for a reliable monitoring program for irrigation water abstraction. Before addressing the above, the next section briefly reviews alternative monitoring systems that have been investigated.

2. Current Situation

Based on the "Study of Groundwater Use and Users in the Northeastern AZB highlands (MWI/ARD, January 2001)" and meetings with the ARD & MWI technical team , the following findings illustrate the current situation:

- The majority of meters installed by WAJ are German made, Spanner-Pollux brand, while those installed by farmers are of different brands and inferior to WAJ meters.
- The WAJ meters have available repair parts while those of the farmers do not have.

[2] MWI/ARD. January 2001. Study of Groundwater Use and Users in Northeastern Amman-Zarqa Basin Highlands.

- The survey proved that farmers, through different ways, practice tampering and vandalism of the meters.
- Installed meters have not been maintained on a regular bases. Since meters are mechanical devices, they need to be inspected regularly to determine and solve problems causing malfunctioning.
- The meter reading function and responsibility is completely separated from repair and maintenance function. There is no coordination between the staff of these two activities.
- Abstraction data is not consistent. The malfunctioning of meters disturbs the reliability of abstraction data.

Table 1: Irrigation Wells Metering Status in the year 2000

Measurement Method	Percentage of wells, All AZB	Percentage of wells, AZB Highlands
Meter	63	61
Estimation	29	31
Meter + Estimation	8	8

3. Alternatives to Discharge Meters for Monitoring Groundwater Abstraction

There are presently gaps in the groundwater abstraction data from the AZB irrigation well metering program. Meters are relatively expensive and require a commitment for continuous maintenance and replacement. Depending on the circumstances and requirements, a close approximation may be all that is needed or justified.

As one means to fill gaps in groundwater abstraction data in the program for monitoring meters, electricity consumption data from the National Electricity Company was examined. By calculating the annual abstraction for the wells where pumps are driven by electrical energy, some of the gaps in groundwater abstraction data can be filled. However, estimation of groundwater abstraction using electrical consumption data is only a useful check on specific well metering data. Since only 43% of the farmers use electrical powered pumps, and the electrical consumption is not all used for pumping. Part of it is used by booster pumps to pressurize the drip irrigation network.

Remote sensing is another method that could be used to verify metering data and to estimate total water abstraction in the AZB. Satellite image sensitivity to different bands of radiation and resolution of area are increasing and improving the accuracy of this tool as a means to estimate the area of specific crops being grown. However, estimation of water abstraction by remote sensing data is still dependent upon theoretical crop water requirements and estimates of water use efficiency. On the other hand, remote sensing data analysis is a reliable method for monitoring changes in cropped area from period to period.

In summary, electrical energy consumption data can be used to estimate groundwater abstraction as a spot check of individual well meter readings. Neither

electrical consumption data nor remote sensing data should be used as replacements for metering in determining groundwater abstraction in the AZB, but they would be considered as supporting tools.

4. Proposed Actions

Based on the review of the current situation, the following steps are recommended to improve the monitoring of agricultural groundwater use in AZB:

- Continue the use of well meter readings to obtain actual measurement of applied water, and supplement well meter readings with remote sensing and electricity data.
- Remote sensing is recommended for monitoring cropped area and wells buyout, and therefore as a support tool for monitoring the implementation of groundwater management options
- Establish a program to improve and upgrade the AZB irrigation well metering. The program needs to include:

  - Establishment of a meter repair and maintenance system
  - Standardization of meters and meters installation
  - Strengthening of metering operation
  - Data reporting and management
  - Water users education and awareness

4.1 Establishment of a meter repair and maintenance system

- Conduct a survey to figure out the number of meters malfunctioning and determine the type of repairs. The meter inspection and repair form shown in Table 2, should be completed.
- Establish a meter repair program, which considers the following recommendations:

  - Meters should be scheduled for maintenance on a regular basis
  - Repairs to the meter should be done on a timely basis, with no delay, to reduce the loss of abstraction data.
  - Assure availability of spare meters and spare parts including meters heads.
  - Repair of malfunctioning meters should start by checking the meter head, prior to other meter parts.
  - All meter repairs should be recorded in Table 2.
  - WAJ “seals” should be placed on the pipe and meter flanges to identify if a meter has been removed and possibly tampered with. Small holes can be drilled through the flanges and a wire can be placed through the hole. A seal can be placed on the wire ends.

Table 2 Groundwater Abstraction of AZB Meter Inspection and Repair Form

Well Number: _____
Well Location: _____

Meter Serial Number: _____ Meter Brand: _____

Date Inspected	Meter Condition / Problem				Date Repaired	Repairs Made	Date Reinstalled	Comments
	Meter Head	Propeller	Other	Description				

- A red metal tag should be attached to all meters stating that ***the meter belongs to the WAJ and it is unlawful to tamper or disturb it***. If a specific meter continues to be tampered with or damaged, a steel box could be constructed and locked around the meter and pipe flanges to discourage these activities.

4.2 Standardization and installation of meters

4.2.1 Standardization of Meters

It is recommended that all non-standard meters, essentially those installed by farmers, need to be replaced by the standard meter type used by WAJ. By having one brand of meter, repair and maintenance will be improved and simplified.

The wells buy out option may make many meters available for use on other wells to standardize the meters. The purchase of replacement meters could be done through the use of the Groundwater Management Fund.

4.2.2 Meter Installation

All meters have specific criteria for their installation in order to assure that the meter operates within its accuracy range (generally plus or minus 2%). The meter must be installed a certain distance both downstream and upstream from flow disturbances, such as, elbows and valves. The distance is usually expressed in the number of pipe diameters. The Spanner-Pollux meters should be installed 10 diameters downstream from flow disturbances. A significant number of meters are not installed to these specifications, as shown in Figure 1. This should be checked during the field inspection to determine if the meter needs to be repositioned.

Figure 2 shows a correctly installed meter. To improve accuracy, new meters need to be installed according to manufacture's specifications whenever possible.

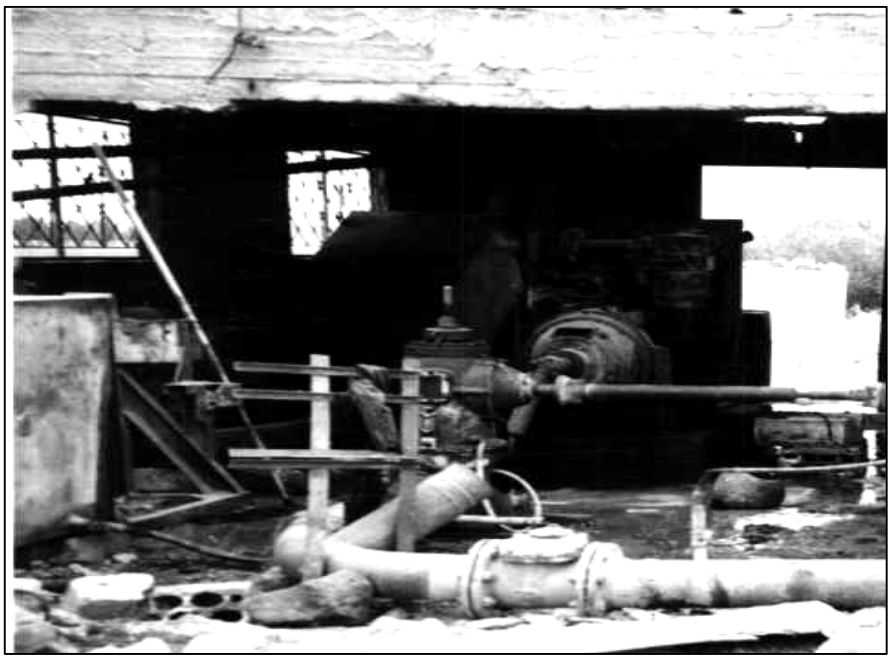

Figure 1: Incorrectly Installed Meter

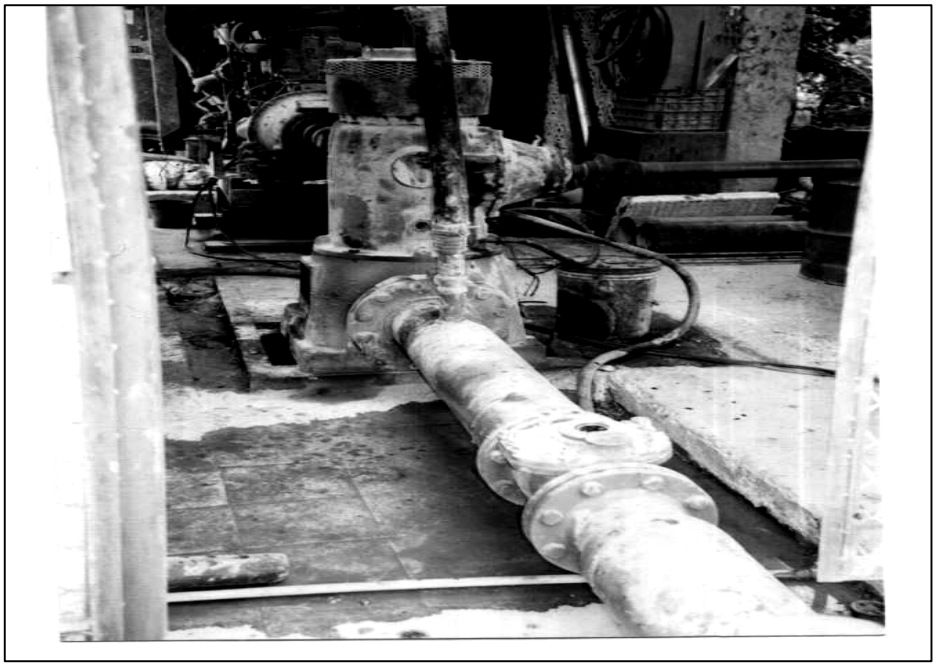

Figure 2: Correctly Installed Meter

Meters are designed to operate under full pipe conditions. If the pipe is not completely full, the meter will over register the flow. A full pipe can be assured if the invert of the discharge pipe is raised to an elevation above the meter.

Due to the design of the Spanner-Pollux meters, there is very little clearance between the propeller and the inside meter wall. Small rock particles can be picked up by the pump, become lodged in the meter, and stop the propeller. A sketch of the meter (see Figure 3) illustrates this problem. If a meter continues to have problems from rock particles lodging between the propeller and the meter wall, a strainer should be installed upstream of the meter to remove the rock particles. WAJ has the strainers in stock but for some reason they have not been installed.

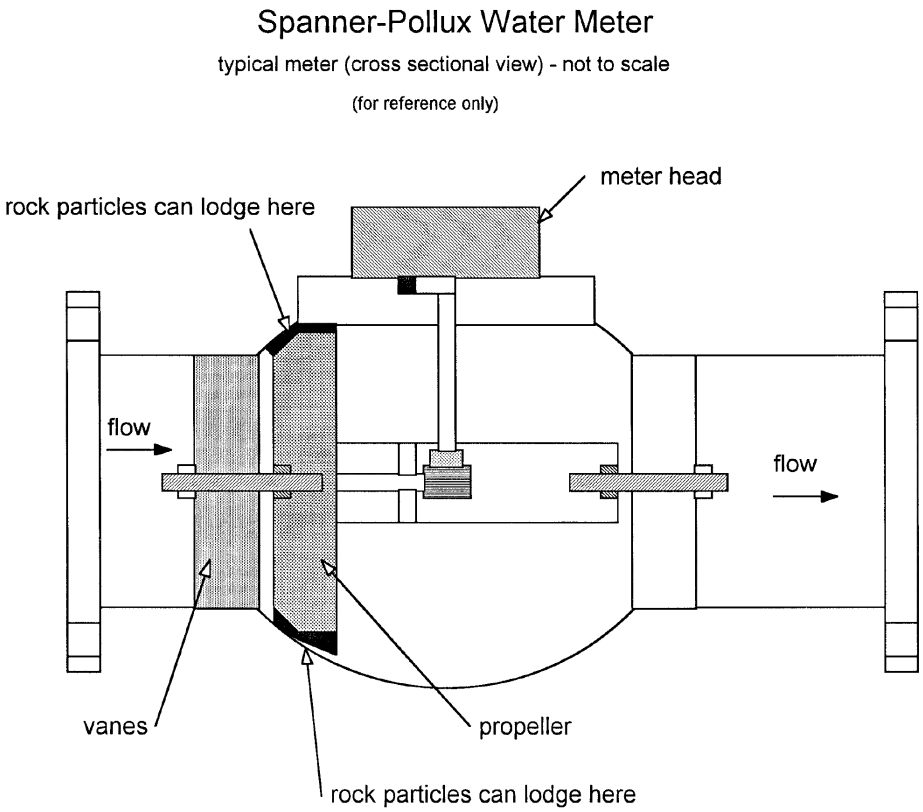

Figure 3: Sketch of Spanner –Pollux meter showing where rock particles can lodge

4.3 Strengthening of metering operation

Currently the meter reading and meter repair/maintenance functions are completely separated activities, as stated in section 2. Employees responsible for these two functions do not interact with each other on a regular basis. In order to have an effective and reliable metering program these two functions need to coordinate their activities.

The following is a description of additional actions needed to strengthen the AZB irrigation well metering program. These actions include:

- Establishment of repair/maintenance crew
- Replacement/rehabilitation of meters
- Training of meter readers and repair/maintenance crew
- Establishment of meter inspection and reading schedule

4.3.1 Establishment of repair/ maintenance crew

As stated earlier, each of Mafraq and Zarqa metering team is planned to have one repair/maintenance crew composed of one technician and one laborer. The estimated cost labor cost and overhead for 2 technicians and 2 laborers for all AZB irrigation meter repair and maintenance is estimated at JD10,656 per year or JD53,280 for Five years (Table 3).

These repair/maintenance crews would have the responsibility to remove, repair and replace irrigation meters in the basin that are beyond the skills of the minor repairs done by the meter reading team. By assigning the teams to specifically work on irrigation meters, the irrigation meters will be given the priority they need. The repair/maintenance crews will work under the supervision of their respective head of the metering team in Mafraq and Zarqa.

In addition, each of the irrigation meter repair/maintenance crew needs to be provided with a mobile workshop truck and tools in order to make repairs or replace meters in the field. This will reduce the time required to make repairs and the decrease the number of trips to well sites. The cost of a workshop truck is estimated at JD30,000 (Table 3).

4.3.2 Replacement/rehabilitation of Meters

The proposed metering replacement/rehabilitation scheme includes:

- Gradual phase out of farmers installed meters: This consists of replacing the malfunctioning meters by WAJ type meters.

- Rehabilitation/Replacement of WAJ meters: This consists of rehabilitating malfunctioning/reparable meters and replacing malfunctioning/non-repairable meters.

Based on the year 2000 irrigation metering statistics presented earlier in Table 1, the expected number of meters, which need replacement and rehabilitation is approximately 110 and 90, respectively. An additional 24 new meters are required for non-metered wells. These numbers will be fine tuned and validated after the meters status survey indicated in section 4.1. As a result the estimated budget for the purchase of 134 meters (110 replacement and 24 for new metered wells) is around JD80,400 assuming JD600/meter, and JD24,100 for spare parts and repairs; as shown in Table 3.

Table 3: Estimated Costs and Personnel Needed to Implement Recommended Action Plan

	ITEM	COST (JD)
1	**Labor costs (Meter Repair/Maintenance Teams) for 5 years**	
	2 Technicians	30,000
	2 Laborers	1,4400
	Overhead (20%)	8,880
	Sub-Total	**53,280**
2	**Mobile Workshop**	
	2 Mobile Workshop Trucks	60,000
	Vehicle use/fuel costs (for 5 years)	12,200
	Sub-Total	**72,200**
3	**Meters Replacement/Repairs**	
	Meter purchases	80,400
	Spare meter parts and repairs (30%)	24,100
	Sub-Total	**104,500**
4	**Training and Computers**	
	Training of meter-readers	2,500
	4 Computers	6,000
	Sub-Total	**8,500**
	TOTAL	**238,480**
5	**Contingencies (20%)**	**47,700**
	GRAND TOTAL	**286,180**

4.3.3 Training of meter readers and repair/maintenance crew

- **Training of meter readers**

In addition to recording the meter readings, meter readers need to:

- Record the crop data on the meter reading form (Table 4).
- Record electricity consumption, if possible
- Measure TDS
- Perform routine inspection and maintenance of the meters

A two-week abstraction estimation-training course is recommended for meter readers. The program should focus on identification of crops, crop water requirement, measurement of cropped area, and estimation of abstraction using electricity consumption.

Table 4 Groundwater Abstraction of AZB Meter Reading Form

Well Number: _____
Well Location: _____

Date	Previous Reading	Present Reading	Pumped Volume	Reliable Yes/No/?	Estimated Volume	TDS	Meter Reader	Crop Types and Areas	Comments

The course is intended to define a practical standard procedure for estimation of abstraction to fill in meter reading gaps. All irrigation well meter readers in Jordan should use this standard procedure. This course would be conducted by a Jordanian Irrigation specialist. The estimated budget of the course is around 2,500 (Table 3).

In addition, meter readers need to be trained in the operation and maintenance of the meters. They should be able to perform minor repairs and replacements to the meters, such as, the replacement of meter heads. A two-day training on routine inspection and maintenance of the meters at WAJ repair shop is recommended.

- **Training of repair/maintenance crew**

A two-week training on inspection, repair, and maintenance of the meters at WAJ repair shop is recommended.

4.3.4 Establishment of meter inspection and reading schedule

During the irrigation season for at least two years, meters should be inspected and read on a monthly basis. This level of activity will illustrate to farmers that the meter readings are important. In addition, the farmers would have more difficulty tampering with the meter operation without detection. The exact day of the visit to the meter should vary a little each month so the farmer will not know when the meter will be checked. If tampering with the meters continues, charging the farmers the cost to remove foreign objects, other than small rock particles, could be considered.

Once a good set of monthly and annual data is established, it will assist with calculating abstraction for periods when meters may be malfunctioning in future periods. After the two-year period of monthly meter readings, the meter reading could be rescheduled to every three months depending upon whether the malfunctioning of meters has been reduced. In addition, monthly spot checks should be made of those meters that are suspected of being tampered with.

4.4 Data Reporting and Management

Currently there is a concern that the calculation of groundwater abstraction is not consistent. In order to respond to this concern, it is recommended that the meter readers be trained to enter the meter reading and other data they collect into a computerized database. Routines should be designed to enable easy verification of the data by the supervisor. After checking the data the supervisor will be forwarding it to WAJ for entry into the oracle database.

4.5 Water Users Education and Awareness

The value of meters can be explained to farmers when conducting the on-farm Irrigation Advisory Service and under the Water User Education and Awareness Program, proposed in the Preliminary Groundwater Management Action Plan (April 2001).

5. References

1. MWI/ARD Study of Groundwater Use and Users in Northeastern Amman-Zarqa Basin Highlands, January 2001

2. MWI/ARD Groundwater Management Action Plan Amman-Zarqa Basin Highlands, Draft Interim Report, April 2001.